

**PIETRA D'ISTRIA: QUARRIES, CHARACTERISATION, DETERIORATION
OF THE STONE OF VENICE**

Lorenzo Lazzarini

*Laboratorio di Analisi dei Materiali Antichi, Sistema dei Laboratori, Università IUAV
di Venezia S.Polo 2468 – 30125 VENICE (Italy) lorenzo@iuav.it*

Abstract

In spite of its lagoon setting and distance from mountains, Venice is one of the richest towns in the Mediterranean area as regards marble and stone varieties due to extensive spoliation of the neighboring ancient Roman towns and to its trading with the Levant. What is considered the true local stone of Venice was brought from the western side of the Istrian peninsula, located on the eastern coast of the Adriatic Sea, between the second half of the 13th century and the end of the 20th century. The Venetians used this stone widely as a barrier against rising water, as well as for architectural elements and sculptures, and exported it to their possessions on the mainland (in the Triveneto and Lombardy), to the south Adriatic shores and to some of its territories in the Eastern Mediterranean (for example to Candia-Crete, Negroponte-Chalkis and Thessaloniki). Istrian stone, when of good quality, is a very pure, compact lithographic limestone of the Tithonian age, and the façades of many Venetian monuments such as the Ducal Palace and many Renaissance and Baroque churches owe their good conservation to it. This paper contains descriptions of the main quarries at Vrsar and Rovinj; reports of the characterization of samples taken from them - minero-petrographical (by OM and XRD) porosimetrical (MI) and isotopical (SIRA) - and an account of the most common deterioration morphologies affecting the Istrian stone used in important monuments in Venice, together with reports of laboratory investigations (SEM+EDS) designed to determine the main micromorphologies, causes and mechanisms of their deterioration.

Keywords: pietra d'Istria, quarries, characterization, deterioration, Venetian monuments

1. Introduction

Despite its lagoon environment and the fact that it is quite a long way from any mountains, Venice is one of the richest cities in the world as regards stone and marble, and use of these materials has played an important part in its long history. Although the very first building materials in Venice were essentially wood and brick, mostly re-used, the façades of the more important buildings were already beginning to incorporate stone, again re-used, by the Late Middle Ages; and as time went on the trend increased. But if we exclude St. Mark's Basilica and a few other buildings it is only from the 14th-15th centuries that newly quarried stone and marble was extensively used, mainly for decorative rather than structural purpose.

In the Gothic and Renaissance periods, Venice was a very colorful city, an *urbs picta*, with façades of red brick, stone or covered with painted plaster, but the monumental Venice we have inherited and the image we have of it is mainly white, from the Istrian stone facades of so many churches and *palazzi*. This stone continues to

play a fundamental role in the city, and indeed it is no exaggeration to claim that Venice, in large part, owes its very survival to it. Suffice to mention its use in the foundations of buildings to stop rising damp, and its excellent deterioration- and pollution-proof qualities with the result, as we shall see later, that neither form of aggression has led to anything more than superficial decay in its good quality varieties.

2. Notes on use and geographical distribution

Reliable evidence of the use of Istrian stone in Roman times is confined to Istria. There are sarcophagi in Rovinj (Rovigno) (some can still be seen in front of the Cathedral of Saint Euphemia) and other artifacts in Poreč (Parenzo) and Pula (Pola), while exports seem to have reached no further than Aquileia, where Istrian stone is rare; indeed the only instance so far recorded is in some of the blocks constituting the harbour wall. It seems to be entirely absent from the other Roman towns of the *X Regio Augustea Venetia et Histria*, where much the most commonly used stone is Aurisina limestone in its various varieties, but especially the ones known as “Granitello” or “Roman Stone” (D’Ambrosi and Sonzogno, 1962; Lazzarini 2000).

We know of no documents or securely dated works that can establish exactly when Istrian stone first arrived in Venice, but its use for sculptural work datable to the second half of the XIII century, such as the carved bases of the columns of *Marco e Todaro* in the Piazzetta (Tigler 1995), and the stone bench against the outer wall of the Treasury of St. Mark’s, is indicative of the importation of small quantities of Istrian stone, which became possible after the acquisition/conquest of Parenzo in 1267 and Giustinopoli (Koper) in 1276 (Rizzi 2006).

Initially, and throughout the 14th century and at least part of the 15th the most common use of Istrian stone was for statuary (Figure 1) (Wolters 1976) and for various features of Gothic buildings (quoins, cable-carved door jambs, frames carved with Venetian dentils, guttering, arches and crockets, etc.) the white of which usually stands out against red brickwork.



Figure 1. Jacopo della Quercia (attr.), the Judgement of king Salomon, 2nd half of the XV c., Ducal Palace, Venice: the surface of Istrian stone is covered by a uniform, natural, white patina.

A clear exception to this rule is the Doge's Palace, where Istrian stone is employed both for structural purposes and to face the façades. Later it was used differently and much more frequently, most of all in block form as a facing material (especially in façades and floors, from the 16th to the 18th century) and as architectural elements such as columns and pillars (Dalla Costa and Feiffer 1981).

One interesting, quite early use of Istrian stone was its employment (already mentioned above) as a foundation material to intercept rising damp and tidal water in the canals, a function it performed much more effectively than a sandstone from the foothills of the Eastern Alps (the Miocenic molasse), which had been the standard material up to the end of the 13th century (Lazzarini 1986; 2006). Large amounts of Istrian stone continued to be used in the 19th century, just two examples being for the Salvi Palazzina and for the coping and other features along the causeway between Venice and the mainland. With the unification of Italy many other stones became competitively available and imports of Istrian stone gradually diminished until they almost stopped altogether in the early years of the 20th century. When Croatia gained control over the territory containing the quarries after the Second World War, extraction ceased completely, firstly for landscape protection reasons (the best quarries were in sensitive coastal locations) and also because of a fall-off in demand. It was only in the 1970s, after the great flood of 1966 and the considerable volume of restoration work in Venice that was triggered by the event, that new quarries were opened inland in Istria, particularly at Kirmenjok (Chirmignacco), and these continue to supply reasonably good quality stone for Venice and the rest of the Veneto.

The Venetians also carried their predilection for Istrian stone elsewhere, especially into the Veneto hinterland. The gates to the Venetian walls around the cities of Treviso and Padua feature substantial and studied use of the stone, which is also present in Bassano, Belluno, Serravalle, Conegliano, Rovigo, etc., as well as in Vicenza and Verona, despite the fact that these two latter cities could (and can) draw on plentiful supplies of good quality local materials (soft limestone from the Berici Hills and from Piovene in the case of Vicenza, and various compact limestones for Verona). In all these towns and cities, as in many other places in Lombardy, Istrian stone was always used for the symbol of the Serenissima, the lion of St. Mark (Rizzi 2001;2006), and the two were also paired to underline Venetian rule much further afield, for instance in Candia (Iraklion), Negroponte (Chalkis in Eubea) and Cyprus (Rizzi 2001). Perhaps the most distant place to be reached by substantial quantities of Istrian stone was Thessalonica (Greece) where, in the Basilica of Saint Demetrius, it is used for the sarcophagus, the baldachin, the supports and the cornices of the tomb of Luca Spadoni (died 1481).

Istrian stone is also found in other cities in the Po valley such as Bologna (for example in the façade of the Cathedral of Saint Petronius) and Ferrara, and along the Adriatic coast, both on the Dalmatian side and in Emilia and the Marche, including a number of monuments in Ravenna, Rimini, Fano and Loreto. It is worth remembering that in these latter places, as in Venice, it was common practice to paint and gild sculptures and carved architectural features made of Istrian stone. There are many

examples of such artifacts with extensive traces of polychromy, including the late Gothic reliefs of the Scuola di S. Giovanni Evangelista and of the Scuola dei Calegheri, and the bases of the statues and the heraldic devices on the Porta della Carta in Venice and, to give a couple of examples from elsewhere, the Lombardesque structure of Dante's tomb and of the portal of the Church of S. Agata in Ravenna. When it was not painted, the surface of Istrian stone was often treated with natural organic substances (such as siccative oils, wax, casein, etc.) which were intended to protect it and conserve for as long as possible the delicate "light beige" or greenish colour that unfortunately tends with time to be replaced by a white patina (see below) or still worse by more or less thick black deposits consisting of pollutant atmospheric particulate "cemented" by gypsum.

3. Nature, genesis and geology, main physico-mechanical properties

From a strictly petrographic point of view, Istrian stone is to be classified as a micritic limestone (Folk 1959) or a mudstone (Dunham, 1962), that is to say a rock formed through the diagenesis of a calcareous mud, composed of very fine grained calcite crystals (< 4 micrometers); it is also compact, with very rare small pores (vugs and fenestrae) (Figure 2). The texture frequently features iso-oriented veins, small nuclei and cavities filled with secondary sparitic calcite. Stylolites, as well as sedimentary joints, are sometimes very frequent, with small deposits of clay minerals often occurring along them, coloured by yellow-ochre. More rare are small clasts of detritic quartz and needles of sericite and chlorite, mainly stilocumulated. In this case joints and stylolites behave as surfaces with minor cohesion, major porosity and planes of preferential decay in the stone.

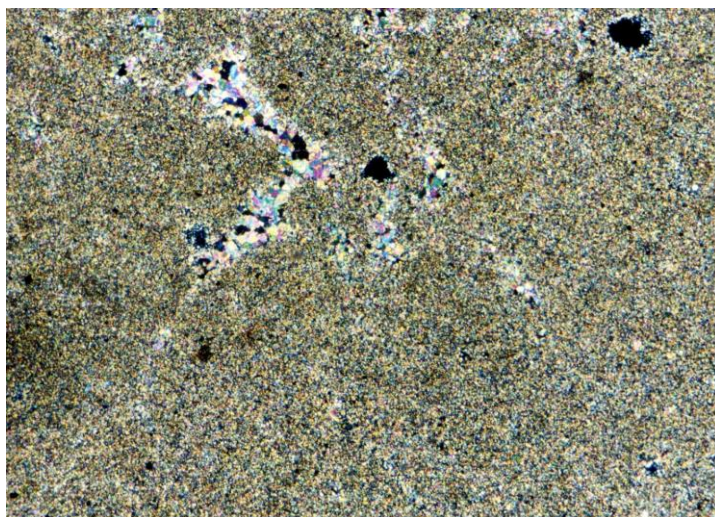


Figure 2. Photomicrograph of a typical thin section of Istrian stone showing its micritic fabric interrupted by few very small vugs and microsparitic veins (N+, long side = 1.03 mm).

Geologically the Istrian peninsula constitutes the western part of a vast Mesozoic carbonate platform currently recognised as part of the Unity of the External Dinarides.

This platform is formed by sediments ranging in date from the Upper Jurassic to the Cretaceous and/or Tertiary (Paleocene and Eocene). Structurally the area features a Jurassic-Cretaceous anticline, with its central part (nucleus) essentially formed of terrains dating from the Upper Jurassic and the sides with Cretaceous formations (Forti 1996). From a general geo-topographical point of view, while the western and southern Istrian areas are mainly characterised by rocks formed in a shallow sea, the rest of the peninsula is composed of tertiary foram limestones and flysch (Crnković 1981; Tisljar et al. 1983) (Figure 3). The former, which are of particular interest to us, originate

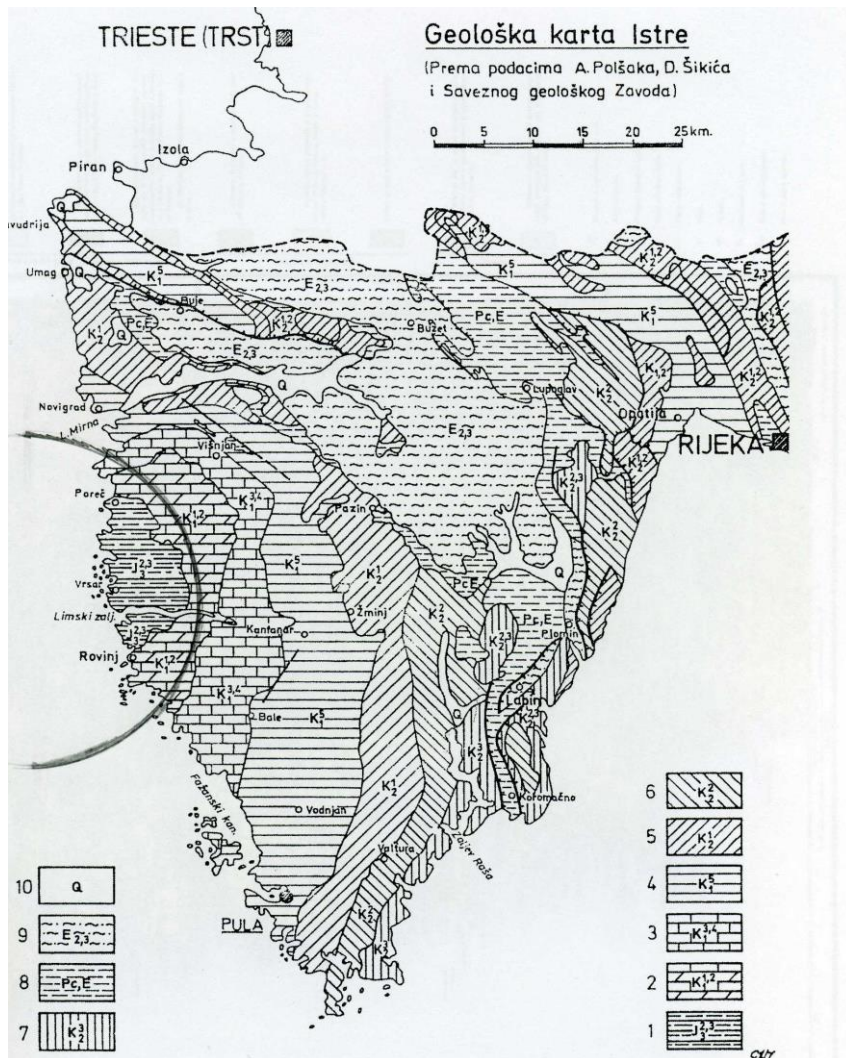


Figure 3. Geological map of Istria (from Crnković, 1981) with the outcrop-area of Istrian stone clearly marked.

through lithification of sediments deposited in various environments such as supratidals, intertidals, subtidals (e.g. peritidals), lagoons and back reefs, but also proper reefs. Such a sedimentary variety is related to the weak inclination of the carbonate platform and to its non-uniform subsidence and varied immersion velocity of the parts, which have influenced the accumulation of the sediments themselves. Factors such as the fluctuation of the sea level have influenced the changes in the sedimentary environments, as well as the sedimentary rhythms and cycles, generating a large variety of carbonate lithofacies which, for their resemblance or provenance, are often associated by non-specialists under the name of Istrian limestone. Also for this reason, the nature, genesis and geology of this stone have often been described in a contradictory way and even today we can read some inaccuracies, often serious ones, which generate confusion.

First of all, "Istrian limestone" is a geological denomination applicable to a typical Jurassic (Upper Tithonian) limestone of mid-western Istria (Figure 3) (D'Ambrosi 1930). The original genetic environment refers to a coastal area of a tropical sea with the presence of shallow water zones and structures such as atolls and coralline reefs, where carbonate muds were deposited about 150-140 million years ago and subsequently transformed into limestone through lithification. This is peritidal limestone, which constitutes the lower part, clearly visible near Rovinj, of a series named "micrites with stylolites of Kirmeniak" by Velić and Tisljar (1988), about 65 m thick. This, of course, was not the only lithotype used by the Venetians, but it was certainly the best and most prized. The limestone on this side of the lithostratigraphic unit was generated following cycles of *shallowing-upwards* and is composed of 3 typical members as follows:

- a thin breccia level with a carbonate-clay matrix formed by the redeposition of materials from eroded marsh deposits transported during a high stationary phase related to the sea level. This *facies* is present, though rare, in Venetian monuments;
- a thick (1-2 m) *mudstone* layer (Dunham 1962) containing stylolites (Figure 1) with rare bioclasts, its upper part containing bioturbation and *fenestrae* structures from desiccation and dissolution by erosion. This reflects a low energy subtidal environment and is the most common *facies* used in Venice;
- a member, not always present in the micrite unit (while typical of the middle and upper parts), characterized by a variable lithology with intraclasts, vadose structures, pisoid coatings and locally by stromatolites. The presence of desiccation cracks and erosive morphologies in the superficial parts indicate intertidal and/or vadose contexts and periods of subaerial exposure. These texturally different *facies* are all fairly well represented in Venetian buildings.

It needs to be said that many other limestone lithotypes belonging to different Cretaceous lithological levels, not easily distinguishable from the ones described above, are used in Venetian monuments. Only a detailed comparative petrographical and geochemical study can lead to a certain determination of the levels that have been accurately defined on site and in the laboratory by Croatian geologists. A first characterization by means of measurement of the stable carbon and oxygen isotope ratio carried out on quarry samples taken at Vrsar (Orsera), Rovinj (Rovigno), Gradina (Geroldia), Kirmenjask, Mondelako (Mondelaco), Valkarin (Valcarino) and Funtane (Fontana) has given encouraging results for the homogeneity of the results

obtained varying very little for ^{18}O (from -2 to -4 of δ per mil PDB) and quite substantially for $\delta^{13}\text{C}$ (from -3 to +2 of δ per mil PDB) (Figure 4).

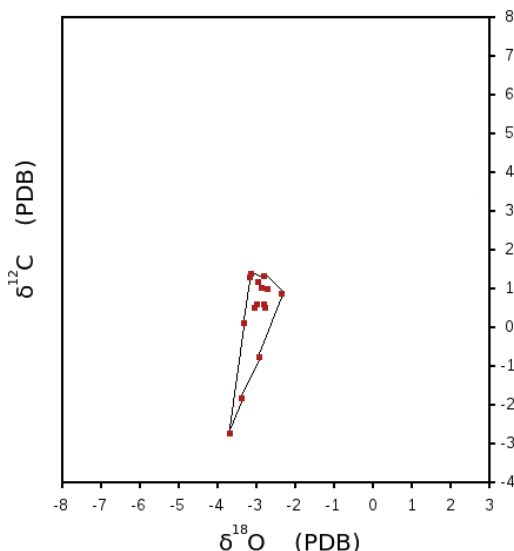


Figure 4. Plot of the stable isotopic data of 15 samples of Istrian stone taken from the quarries of Vrsar (5), Rovinj (5), Mondelako, Kirmenjask, Funtane, Gradina, Valkarin (1 for each site).

Of the physical-mechanical properties of Istrian limestone, the most important is certainly its very low porosity and the consequent high compactness, though this refers to the best quality stone, that is to say to the thickest and purest strata containing few stylolitic levels extracted at Vrsar and Rovinj. Porosimetric measurements carried out through mercury intrusion (MIP) on some samples taken from the layers described above, have given the following values of total porosity and related density:

Porosity = 0.5-0.6%; apparent density 2.67-2.69.

Only one sample containing a stylolite has given the respective values of 1.1 and 2.64, which can be considered equivalent to a stone of medium-low quality. A typical pore radius distribution for a stone of good quality is shown in Figure 5, where it can be noted that the majority of the pores are situated in a range between 9 and 90 micrometers, with a low percentage of pores between 0.03 and 8 micrometers; the average size of the pores is around 16.7 micrometers. These low values of total porosity and small percentages of fine pores, below one micron, qualify our stone as very compact and frost-resistant. The remarkable compactness also determines a good hardness: 20 separate measurements according to the Knoop micro-scale gave an average value of 1510 MPa, which is more than adequate for a material that has to withstand incision and wear and can thus be used for flooring. The use of Istrian limestone both for internal and external floors has been well tested in Venice and other cities of the Veneto region through the centuries: one disadvantage of this use, common to all limestones, is that the surface acquires a polished finish with long use

and can therefore become slippery. The imbibition coefficient in water has been calculated to be around 0.10-0.20 (Calvino 1967) this low value makes Istrian stone an ideal barrier against rising damp. In this regard, the correct installation of the stone blocks/slabs is very important; possible discontinuity planes need to be oriented perpendicularly to the direction of the water movement.

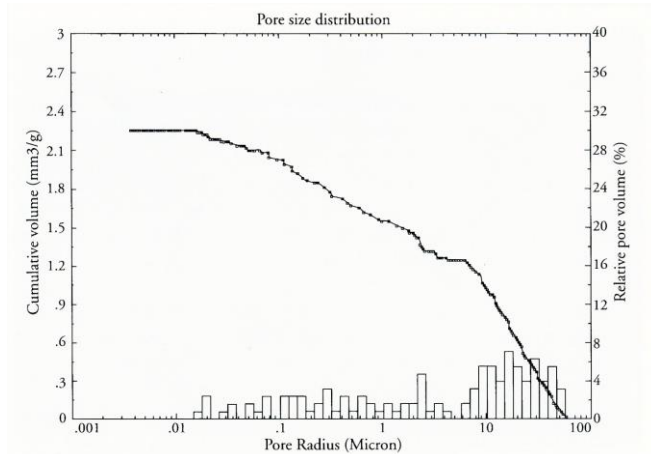


Figure 5. A typical porosimetric diagram of a sample of good quality Istrian stone as obtained with the mercury intrusion technique.

Tests on mechanical resistance given in the literature (Calvino 1967) indicate average uniaxial compression strength perpendicular to bedding of around 1800 Kg/cm², and parallel to bedding around 1350 Kg/cm², which classifies Istrian limestone among the best available limestones in nature for structural architectural use. The tensile strength measured on three stone samples from Vrsar has given an average value of 170 Kg/cm².

4. Ancient-modern quarries and their exploitation

In the Venetian Republic all stone quarries and mines in the "mainland and marine states" were under the direct control of the Council of Ten. An ordinance associated with the Guild of Stonecutters is known to have been in existence in 1307 and in 1440 the *Provveditori al Sal* sent appointees to bring stone from Rovigno (Dal Borgo, undated, and 2006). In the second half of the 17th century, and until the Fall of the Serenissima, responsibility passed to the *Deputati alle Miniere*, always under the control of the Council of Ten (Dal Borgo, undated, and 2006). In Istria there were numerous limestone quarries, known as *pedrare*, and by 1670 there were several thousand. The material extracted consisted not only of building stone but also chips for calcining in lime kilns and assorted stones for other uses and in general, quarrying perhaps constituted the principal economic resource in the Istrian peninsula for several centuries. This activity has never been studied in depth and still less is there a

comprehensive inventory of the ancient quarries. Many place names, such as Gradina, Mondelaco, Signori, Soline, Fontana, etc. are often cited in literature but whether or not the quarries in these places yielded true Istrian stone needs to be checked from a strictly geo-stratigraphic point of view. For this and other reasons we have basically confined our attention in this paper to the two largest known quarries – the ones at Vrsar and Rovinj; they are also the most important, most famous and best preserved and can certainly be considered as typical of the Venetians' quarrying activities in Istria. Other smaller quarries have been explored but much less intensively studied.

The quarry at Vrsar is located to the west of the town, on the slopes of the hill on which it stands, and, which descend quite gently down to the sea (Figure 6).



Figure 6. A view of the eastern part of the quarry of Vrsar (Orsera): the town is visible in the background.

The fact that the rock strata are showing a slightly inclined dip slope, at an angle of 5-15°, so blocks could be quickly transported down to the shore where they were easily loaded onto barges (*burci*) or *rascone* for transport to Venice, meant that the Vrsar quarry was much preferred. It consists of several amphitheatre-shaped *loci* facing the sea, all of different sizes and depths, with faces varying in height between 7-8 and about 15 metres. Moving from north to south, there are two big *loci* and then an enormous flat area, which may also have been used for temporary storage of blocks; at the centre of the second *locus* is a trench where detritus from block-trimming operations was dumped. The recent removal of small piles of debris against one of the quarry faces on the northern side of the flat area has revealed well-preserved traces of point chisel cuttings. The marks are from 25 to 45 cm long, at an angle of about 60-70°, and they are what remains of the fissure that was cut to separate the blocks from the hillside. Other traces have certainly been lost as a result of extraction work undertaken a few decades ago, when the quarry was partially converted into a campsite

and an open-air museum of modern sculpture. The quality of the stone quarried at Orsera is excellent: it is ivory in colour, sometimes of colder shade tending towards light grey; it is very compact and has a typically conchoidal fracture. Blocks detached from the rock face can reach a thickness of up to 1.5 m; the best are free or almost free of stylolitic planes.

The quarry in Rovinj is enormous, without doubt the biggest Istrian stone quarry to have been opened in antiquity: an approximate calculation suggests that it has yielded perhaps 700,000 m³ of material. It lies a few kilometres to the south of the town, on the northern and western slopes of Cape Montauro (Zlatni). It has an inverted L-shaped ground plan, with the short side pointing north and the long side west. The former runs east-to-west for about 150 metres (Figure 7), with a flat open area about 45 metres deep in front of it and a quarry face about 30 metres high. The stone is quarried in blocks about 80 cm thick, which are anti-dip slope oriented with a 15-20° towards the south; the thickest block ever measured was 135 cm.

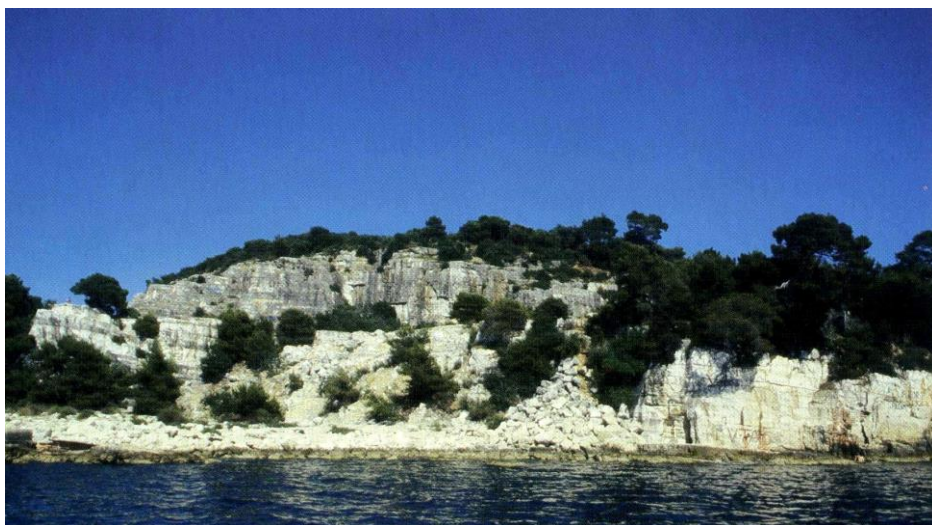


Figure 7. The western front of the large quarry of Rovinj (Rovigno) as view from the sea.

There are very few traces of ancient quarrying, and what remains, in the central part, is poorly preserved, although there are clear signs of terracing; evidence of modern quarry-drill holes suggests a limited amount of recent extraction work. Opposite this side lie four columns still in the position where they were stacked in the past. They are 4.30 metres long, with shaft diameters of 58 and 45 cm and no entases. They were probably abandoned in the 19th century near a small stone-loading wharf, where a number of more or less squared blocks of stone are also piled. The western quarry face is twice as long as the northern one and it has two levels and two faces. The side of the level near the sea shore is shorter, about 15 metres tall at the most and poorly conserved, with evidence of recent quarrying, which has destroyed all trace of ancient workings, and what was probably the structure of a second small wharf for loading stone. The upper level, however, contains the most interesting signs of ancient workings that the present writer has observed in Istria. The terracing is still visible,

though only in part of the face, which at its highest reaches perhaps 40 metres, and since exploitation was conducted in a very rational fashion, from top to bottom, the face is now almost vertical. In front of this quarry-face there is an open yard, about 60 metres long. In one part of this there is a 10 cm-wide groove marking the cutting lines of an uncut block (8.50 metres along its longest side and with a semi-cuspidate shape, 2.50 metres along its sloping side), though it is difficult to imagine what kind of artefact it would have been used for. In various parts of the quarry face it is still possible to make out the 60° sloping marks left by a long point chisel (on average the marks are 25 cm long, like those found at Vrsar) used to cut the fissure around five sides of a block to separate it from the rock face. Evidence that extraction was carried out with the usual system adopted in antiquity (Waelkens 1990) is provided by a 10-13 cm-wide groove and wedge holes needed to separate the block of stone from the sixth side, where it was still attached to the quarry face. These holes are about 30 cm long by 24 deep and 7-10 cm wide and are often positioned inside the fissures described above. Extraction as carried out by the Venetians, therefore took place along the grain, i.e. exploiting the naturally layered fault-lines of the stone, and according to the following operational phases:

- starting from the top, a terraced rock face was prepared, probably with the use of picks to remove the "*cappellaccio*", i.e. the more deteriorated surface layers of the outcrop;

- point chisels were employed to free the block on three sides (two vertical and the lower horizontal); point chisels were then used to chip away a groove along the upper part of the remaining vertical side; this groove was then progressively deepened and/or metal wedges were driven in until the block became detached from the rock face.

The stone quarried at Rovinj is the best: it has an ivory white colour, is extremely compact and shows a conchoid fracture pattern with few stylolitic planes and stratification joints approximately every 60-90 cm. The thickest stratum measured about 110 cm in thickness. Other important ancient quarries were located in Kirmenjak, Funtane, Gradina (Geroldia), Kloštar (S.Michele di Leme), Mondelako and Valkarin.

Once the Istrian stone reached Venice after a voyage of 75 nautical miles it was worked by *tajapiera* or stonecutters, of whom, to judge by the number of place names alluding to their presence, for example between the Basilica dei Frari and the Rialto bridge, there must have been large numbers; for the most part they carved artifacts by commission, but they also produced "standard" pieces such as well-heads, a famous example of which stands in the centre of the stone-cutter's yard beside the Church of San Vidal in the painting of that name by Canaletto, now in the National Gallery in London (Figure 8).

Istrian stone, like all very compact limestones, is difficult to sculpt, especially by comparison with a true marble: it splinters easily and shows a conchoidal fracture, it doesn't allow the sculptor full control over the effect of his chisel blows and fine detail is difficult to obtain. On the other hand it lends itself well to finishing with facing hammers, including toothed types, it is easy to smooth and polish and with its compactness it provides good surface support for gilding and paint.



Figure 8. Antonio Canal (Canaletto), Detail of "The stonemason's workshop at S.Vidal", The National Gallery of Art, London.

The huge popularity of Istrian stone in Venice was also connected with the fact that there was no wastage. Old Venetian stonecutters still have a saying that Istrian stone is like a pig (in Carrara the same thing is said about marble). Any material left over from primary usage was “burned” to make lime or to provide bedding for floors or specially ground for inclusion in *terrazzo alla veneziana*. Even fine powder-*spolveron* in Venetian dialect-was exploited for the production of lime-based *marmorino*, a form of plaster resembling marble that was widely used in Venice in the 16th-19th centuries, and, which is once again very popular.

According to Peter Rockwell, an American sculptor who has recently worked with Istrian stone, it is more difficult to work along the grain (i.e. parallel to the joints), because it is more brittle and splinters more easily than if it is worked “against the grain” (Rockwell 2006).

5. Notes on the deterioration of Istrian stone in Venice

The commonest general form of deterioration in Istrian stone is “whitening” due to carbonation and sulphation on the surface of Venetian artifacts, which prevents the viewer seeing the true color and nature of the stone. Rain water changes the color of

the stone on exposed surfaces so that it becomes a uniform white, due in the past to the dissolution of its principal component, calcite (primary), which forms calcium bicarbonate in the presence of carbon dioxide. Calcium bicarbonate is a soluble salt that precipitates into calcium carbonate (secondary calcite) through evaporation. This is normally extremely fine and very pure, so brilliant white, and forms layers of varying thickness that adhere to the primary calcareous substratum. Where it is well conserved (in the parts of Venetian monuments that are most exposed to rain) it normally reaches a thickness of a few hundred micrometers and constitutes the true natural patina of Istrian stone. Over the last two hundred years and more, this patina has become increasingly rare in Venice because of the atmospheric pollution caused by sulphur compounds, which, especially after the Second World War and until the mid-1970s, were particularly abundant in Venice. It is well understood that sulphur compounds can generate sulphuric acid, which easily reacts with the calcium carbonate in the stone, and still more easily with the extremely fine layer of patina described above, to form gypsum (calcium sulphate dihydrate): the reaction occurs in liquid phase. When observed under an optical microscope (Figure 9) or a scanning electron microscope (SEM) (Figures 10 and 11), this superficial gypsum features a characteristic growth of fibrous-radiated crystals perpendicular to the surface.

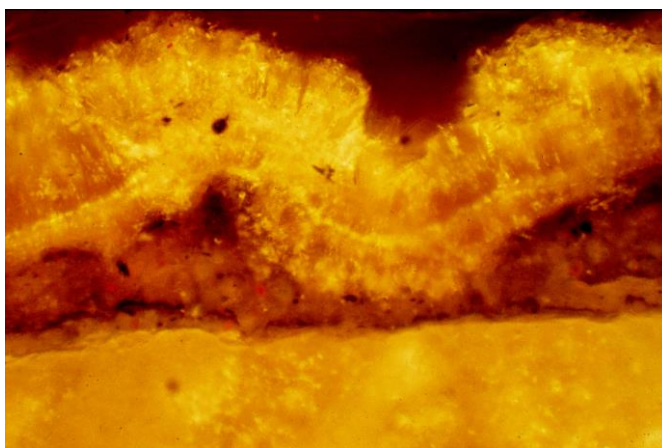


Figure 9. Photomicrograph of a polished section of "whitened" Istrian stone showing re-precipitated secondary calcite mixed to fibrous radiated needles of gypsum perpendicular to its very surface (reflected light, long side = 2.10 mm).

Though it is very soluble in water (2.4 gr/ l at 20 ° c) it becomes quite stable even on moderately rain-washed surfaces because it dissolves and easily re-crystallizes from remaining residues. It thus helps to form the white patina (whitening) that can now be found on calcareous surfaces, which remains on the fingers in the form of a white powdery coating when they are brushed over the surface concerned. If these fine layers of calcite + gypsum constituting the patina also contain carbonaceous particles left over from the combustion of wood (irregular in shape and size) or fossil fuels (globular in shape and generally of the same size), as in the inner layers of the deposits seen in Figures 10 and 11, the result is a slightly greyish patina. If then these particles, which appear under the SEM like microscopic, high-porosity sponges, are more abundant, the

patina becomes an opaque, black crust, which constitutes a disfiguring grime that is dangerous for the surface as demonstrated by numerous papers (one of specific interest for Istrian stone is that of Maravelaki and Biscontin 1999).

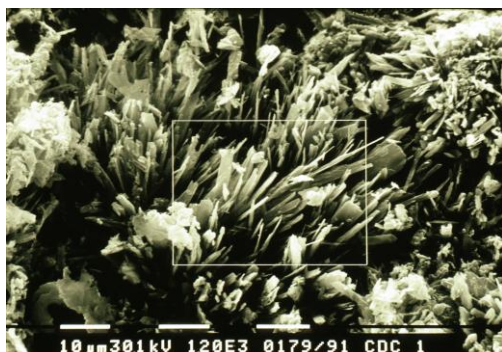


Figure 10. SEM photomicrograph of the same sample of Figure 9 showing the isoparallel growing of gypsum twinned crystals.



Figure 11. Detail at higher magnification of the area marked in Figure 10 showing some corroded (by rain/condensing water) heads of the gypsum twins.

In earlier centuries it was often common practice to protect stone surfaces from rain and other atmospheric agents by covering them with various types of organic substances such as those mentioned above. The result was the formation of artificial patinas that were different from the natural forms and frequently colored by the addition of pigments such as ochre to the organic substances; this conferred a uniform color and texture to the stone. Artificial patinas tend over time to react with calcareous substrata and to mineralize, i.e. to become inorganic, and form, for example, calcium phosphates and oxalates. Patinating treatments of this kind are sometimes original (applied by the sculptor) and sometimes applied later, during conservation work. We know the composition of many of the latter treatments from contemporary documents (Piana 2006), and we know that they were applied to “accompany” restored areas (whether replaced or thoroughly cleaned) to the still dirty surrounding areas. A well known Venetian instance is that of the façade of the Libreria Sansoviniana; the Istrian stone of the part facing the campanile, which had to be entirely rebuilt after the bell-tower fell down in 1902, was “blackened” to make the color of the new stone match that of the old stone on either side. These “restoration” patinas are certainly not

“*nobilis*” (noble) like the original ones, and, especially if they are disfiguring, as in the case just cited, should certainly be removed. However, it is probable that the façades in question were patinated at the very beginning with a light color application designed to give a uniform appearance by evening out the various shades of Istrian stone in the different elements (as confirmed by the stratigraphic sections of samples taken from the façades themselves). Original treatments will also have included preparatory layers (of red/yellow bores) for gilding of anathyroses and outlines to define levels and relief details. And this became common practice in the 16th and 17th centuries, but also later, as clearly confirmed by the results of laboratory tests on these preparatory layers present on the surfaces of other Venetian monuments such as the Procuratie Vecchie, the Ala Napoleonica, and on the tympanum of the Church of the Tolentini.

Despite the absence of specific artificial aging research in controlled conditions it appears clear from the empirical evidence of direct observation of the state of conservation of a very large number of Istrian stone artifacts dating from the 13th to the 19th century that this material can be listed amongst the rocks that will last for 5-10 centuries according to the Salmoiraghi scale (Calvino 1967). Though empirical, this appraisal may be considered generally valid, with the caveat that it applies only to stone of good quality, as specified earlier. Indeed, if the stone is of poor quality, especially if it contains even a small fraction of clay (often visible to the naked eye because it gives an overall yellowish, greenish hue to the stone) it tends to deteriorate structurally and to crumble. Otherwise it presents good resistance to salt crystallization and to the freeze thaw cycle, the two main causes of physical decay found in Istrian stone used for the external parts of Venetian monuments.

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